E/CONF.39/A/126
17 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.1.1

Finland

FUNDAMENTAL GEODETIC OBSERVATIONS IN UNSURVEYED AREAS

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No.1567
A.1.1.

Fundamental Geodetic Observations in Unsurveyed Areas.

by
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The importance of a map for the economic building-up of a country is selfevident.

For mapping and other surveying measurements it is necessary to have a continuous fundamental geodetic fixpoint network in one and the same system over the whole area in question. For each fixpoint the horizontal and the vertical coordinate must be measured with a proper accuracy.

In the countries where maps have been made for centuries, they were first made upon limited areas which often lay apart from each other. When these areas were later enlarged and came into contact with others, there were discrepancies between different maps and different coordinate systems. To remove the discrepancies, geodetic measurements over the whole area in question were necessary.

In the countries upon which no large scale maps have yet been made, the circumstances, as far as geodetic measurements are concerned, are better than in the countries where it has been necessary to patch up and alter old maps and coordinates. In the former case it is possible to measure a general fundamental geodetic network over the whole area before mapping is started and hence no discrepancies in the maps are to be apprehended.

The classical method, to establish a fixpoint system, the geodetic triangulation, is a laborious and time-consuming one. The modern methods, some of them already in use and some under development, offer possibilities to establish a fundamental geodetic fixpoint system over large areas in a short time and at a low cost, as compared to the old methods. The following methods, in the order of their accuracies, can be mentioned here :

- Astronomical latitude and longitude determinations.
- Reduction of the astronomical determinations by the aid of gravity measurements into a world-wide system.
- Use of artificial satellites in geodesy.
- Distance measurements with Shoran and corresponding apparatus
- Stellar triangulation.
- Trilateration with tellurometer and corresponding apparatus.
- The classical triangulation.

The astronomical determination of the latitude and the longitude can be performed with a transit instrument or astrolabe under field conditions with an accuracy of about 10 meters. This is satisfactory for many purposes.

The results of the astronomical determinations, however, concern the actual physical plumb line. This deviates from the theoretical vertical direction and even in a flat country the deviation can change in an area of some tens or hundreds of kilometers several seconds of arc, which corresponds to an error of hundreds of metres in the distances and the directions between the observation points.

The errors caused by the deviation of the vertical can be reduced essentially by determining the direction of the actual physical plumb line by the aid of gravity measurements. This method requires a dense gravity point net in the neighbourhood of the astronomical point. For the other regions the gravity measurements can be sparser the farther the region is situated from the astronomical point. For the distant regions the published gravity measurements can be used and the special gravity determinations are necessary in the local area only. These can be carried out in a relatively short time. Depending on the density of the gravity measurements which are available for the computation of the deflection of the vertical in the world-wide geodetic system, the reduced astronomical coordinates have an accuracy of a half second of arc which corresponds to a linear error of 30 metres. 1).

The technique of using artificial satellites in geodesy is as yet at a very early stage of development. Hence, it is difficult to say how high the accuracy will be that can be attained in the near future. Until now optical tracking has been mostly used, but this technique is strongly dependent on weather conditions. Electronic methods for tracking are independent of weather and may be of great and important service to the satellite technique. In any case, the accuracy of these methods comes close to the accuracy of the gravimetrically reduced astronomical coordinates.

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1) Heiskanen, W., On the world geodetic system, Veröffentlichungen des Finnischen Geodätischen Institutes No. 39 (1951).

2) When using the afore-mentioned methods the determination of the location of a point is an individual procedure, not dependent on any other point. Thus the points to be determined can be situated at any distance from each other and thus they can be located in desired areas of the territory to be surveyed. This is, of course, a great advantage, especially in a country where no geodetic points have been available. The accuracy here, however, is relatively low and not satisfactory for most of the modern surveying or other measurement work. When greater accuracy is desired, the geodetic points must have direct or indirect visibility, optical or electronical, between them. This condition limits the distances between the points to some hundreds of kilometers by the indirect, and to some tens of kilometers by direct visibility.

The electronic distance measurement technique has been developed since the Second World War. In the form of Shoran this method has been used to a large degree in Canada. 3) The distances of 100-600 km between geodetic points are measured by the intermediation of an aeroplane flying midway between the points, the distance between which is to be measured. The observation points form a triangle net, the sides of which are measured. The accuracy of this method, the trilateration, in the actually performed measurements has been 1/50000 - 1/100000, which corresponds to an accuracy of some meters. This method has given a highly usable geodetic coordinate system in areas where no accurate geodetic measurements have been made earlier, for example in Northern Canada. In addition, this method is fast; in Canada 92 points covering 5.2 million square kilometers were measured in the course of one year.

Reaching a greater accuracy for a triangulation net where the side lengths are several hundreds of kilometers, seems possible by the aid of a method suggested and experimented in Finland. In this method, stellar triangulation 4), light signals which are elevated by the aid of a balloon or a rocket to the height of tens or hundreds of kilometers respectively, are photographed from two geodetic stations against the starry sky. Using the stellar

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2) Kaula, W.M. Symposium on the use of artificial satellites for geodesy, Bulletin géodésique, 65, 193-196 (1962).

3) Ross, J.E.R., Canadian Shoran effort 1949-1953, Empire Survey Review, Vol.XII, 242-254, 290-303 (1954).

4) Väisälä, Y. and Oterma, L., Anwendung der astronomischen Triangulationsmethode, Veröffentlichungen des Finnischen Geodätischen Institutes No. 53 (1960).

coordinates the direction of the line from one geodetic station to another is computed. This procedure is repeated and the directions of all the sides of the triangulation network are measured.

The stellar triangulation surpasses the classical triangulation in that, the sides of the triangles can be lengthened essentially and that the effect of the refraction because of the great elevation of the light signals is reduced to a fraction. Hence, the accuracy of the vertical coordinates matches the accuracy of the horizontal coordinates. The first experiments in Finland gave an accuracy of 1/200000. In addition to this the stellar triangulation is independent of the irregularly changing plumb line direction.

A net measured with Shoran or with stellar triangulation is not dense enough for actual surveying purposes. The net can be made denser by aid of trilateration with electronic distance measurement apparatus, such as the tellurometer 5) or similar device, or by classical triangulation. The trilateration cannot as yet give as high an accuracy as the triangulation, but the former is faster and more economical. These properties must be considered more important at least in areas where no geodetic coordinates are available.

A greater density of the geodetic points than that determined with the fundamental geodetic measurements listed above, is required for classic mapping and photogrammetric mapping. In that case triangulation, trilateration, traverses and, especially, photogrammetric triangulation are to be used. Those methods are not the subject of this paper.

The fundamental geodetic determination, such as astronomical determinations, Shoran measurements, the satellite techniques and stellar triangulation, require relatively expensive equipment. Also the personnel needs a long academic and field training. It seems advisable, therefore, that in the countries where no geodetic equipment or personnel are available, these measurements generally be carried out by the international organizations or by the countries which own the needed equipment and personnel.

The tellurometer and corresponding measurements are not so costly and do not require such long training. In addition, the tellurometers can be used in local surveys and in many other measurements except the fundamental geodetic work. Thus it seems advisable that an effort be made to have the tellurometer measurements, which may have been started with foreign aid,

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5) Wadley, T.L., The tellurometer system of distance measurement, Empire Survey Review, Vol.XIV, 100-111, 146-160 (1957).

carried out as soon as possible with the country's own equipment and by its own personnel. The training of the personnel can be arranged to take place in connection with the possible measurement which foreign personnel at the beginning carries out. If no measurements of that kind have been made, the training can be arranged by the aid of experts of the United Nations Technical Assistance Administration.

In geodesy as in all advanced technical fields the terminology in the countries where there has been no activity in that field earlier, first comes from the language of the country from which the method is adopted or where the equipment originates. In order to intensify the activity it is necessary to create the country's own terminology as soon as possible and to prepare at least elementary instructions in the language of the country. By so doing the elementary training is promoted and in addition to this, only when using their own language will people feel that the new technique is their own. Only then may one expect such initiatives and new ideas, which are capable of advancing the investigation of geodesy.

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